VANCOUVER ISLAND ROOSEVELT
ELK/INTENSIVE FORESTRY INTERACTIONS

Problem Analysis

INTEGRATED WILDLIFE INTENSIVE FORESTRY RESEARCH

Province of British Columbia

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Problem Analysis

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Summary

Roosevelt elk occur on Vancouver Island at their northern-most natural distribution and are the only indigenous population of this subspecies in Canada. Elk habitat requirements are not considered in present silvicultural planning and practices (i.e. thinning, fertilization, site control, site conversion, commercial thinning). The magnitude and duration of impacts of these practices on elk ecology are not well understood, though it is apparent that many of the impacts could adversely affect elk production. Thus, intensively managed regenerating stands, which in future years will comprise the majority of forest habitats on Vancouver Island, have the potential of severely reducing the elk population unless a coordinated elk/intensive forestry planning system can be derived.

Presently, information on Roosevelt elk ecology in second growth (or regenerating) forests on Vancouver Island is non-existent. In order to develop a coordinated elk/intensive forestry management system, research on elk ecology in second growth forests is required. Research needs can be broken into the following major divisions:

(1) Habitat Utilization

a) The important physical characteristics of thermal cover including size, shape, age of stand, elevation, slope, aspect, degree of canopy closure and availability of forage. An important associated question is: can regenerating stands of 60-80 years of age (approximate rotation period) serve as adequate thermal cover? Under what conditions?

b) The important physical characteristics of security cover including height and stand density.

c) The minimum area requirements for security and thermal cover patches.

d) Calving cover availability and requirements.

e) The importance of juxtaposition of cover patches with forage areas.

f) The seasonal food habits and preferred forage species.

(2) Vegetation and Physical Environment Parameters

a) The influence of silviculture treatments on plant species quality, quantity, availability and composition.

b) The influence of spacing debris on elk mobility and utilization.

c) The influence of silvicultural treatments on physical environmental parameters such as snow depth, snow density and air temperature.

(3) Animal Condition

The relative condition of individual elk in managed and unmanaged forests, and how this condition responds to different silvicultural treatments and/or enhancement projects.

(4) Population

The influence of silvicultural treatments of population condition and growth.

(5) Predation

a) The response of predation to silvicultural treatments.

b) The impact of predation on elk population, individual animal condition and habitat utilization.

(6) Habitat Enhancement

a) The feasibility and benefits of extensive propagation of forage species.

b) The effects of high site conversion on elk habitat.

c) The long term and short term effects of non-silvicultural fertilization.

Due to the paucity of present knowledge of Roosevelt elk ecology on Vancouver Island, it is recommended that research needs be considered in two frames of reference; an immediate and a long range frame. The immediate frame is necessary prior to extensive hypothesis testing in order to establish adequate baseline data (i.e. home ranges, migratory habits, abundance, productivity, present habitat use, etc.). The long range frame of reference should be concerned specifically with testing hypotheses about elk-silvicultural interactions. This frame will investigate and provide information on a series of habitat-animal related questions. Solutions to these questions should provide the basis for developing an elk/intensive forestry management system applicable to Vancouver Island.

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1 INTRODUCTION

Roosevelt elk are the second-priority species on Vancouver Island in terms of management effort. The increasing demand for consumptive use is evident since the initiation of the limited entry hunting system in 1977, with applications far exceeding available permits. The objective of increasing elk populations to help satisfy demand has been identified in provincial and regional species management plans. The potential for increasing the elk population on Vancouver Island is dependent primarily on the integration of habitat requirements with intensive forest management, as the majority of Vancouver Island is committed to fiber production. Management-oriented research on elk ecology and intensive forestry interactions is thus required to provide the biological information necessary for effective resource integration.

Silvicultural practices in second growth or regenerating forests on Vancouver Island are proceeding without consideration of wildlife requirements. A problem analysis initiated by the British Columbia Ministry of Forests (MOF) (Ellis 1980) examined the major wildlife-forestry interactions and presented a number of wildlife research needs which might help solve wildlife-forestry conflicts. General elk research needs were examined in the analysis. Since completion of the MOF problem analysis, intensive silviculture has proceeded while elk research and management needs have not been addressed.

The present analysis, funded as part of the Integrated Wildlife Intensive Forestry Research (IWIFR) program, examines problems associated with Roosevelt elk/intensive forestry interactions on Vancouver Island. The primary intent is to examine elk research needs as the first step in a 5-year elk research program.

2 DEFINITION OF TERMS

The following terms are defined in the context of this problem analysis:

Animal condition - a measure of the physical health and fitness of an individual (as indexed by body fat etc.).

Dispersal - movement of individuals into or out of populations.

High-lead scarification - crushing and uprooting brush and unmerchantable hardwoods by cable yarding with heavy weights.

High site type conversion - reclamation of a potentially valuable understocked parcel of land by decreasing competition from non-commercial species and increasing stocking of commercial species.

Home range - that area traversed by an individual in its normal activities of food gathering, mating, and caring for young, over a specified period of time.

Natality - birth rate.

Population condition - measure of the health and fitness of a population (as indexed by productivity, rate of increase etc.).

Second growth forest - immature forest ecosystem (secondary succession) resulting from logging activities; also referred to as regenerating forest or re-growth.

Silvicultural fertilization - broadcast fertilization of an area to enhance the production of commercial tree species, usually carried out after thinning activities.

Silvicultural treatments (practices) - intensive forestry activities undertaken to enhance production of commercially valuable tree species including thinning, silvicultural fertilization, high site conversion, and commercial thinning.

Slash and burn - felling all live and dead hardwoods; understory shrubs usually desiccated with herbicides and broadcast burned by mass ignition.

Spray and burn - herbicidal treatment of standing unmerchantable hardwoods and brush, without slashing, followed by broadcast burning; most often applied in low brush shortly after harvesting merchantable overstory.

Thinning (spacing) - reduction in the number of commercially valuable trees per unit area to decrease intraspecific competition and increase growth rates.

3 OBJECTIVES OF THE PROBLEM ANALYSIS

The objectives of the present analysis are to:

1. Define the elk/intensive forestry problem, with a discussion of its scope and each of its components.
2. Present a literature review and discussion of present problem-related knowledge.
3. List each of the problem-related unknowns (research needs).
4. Recommend studies to solve each of the unknowns.

4 THE ELK/FORESTRY PROBLEM

The intensive management of elk and forests is best described as a land management problem. Forest management practices alter forest habitat, resulting in changes in the amount of forage and cover available for elk. Certain changes may be beneficial to elk, whereas others may be detrimental. The major problem is that in many circumstances the magnitude, timing, and duration of forestry impacts on vegetation and elk are not well understood; therefore it becomes difficult to integrate elk/intensive forestry planning through silvicultural modifications. Thomas (1979:104) aptly summarizes the problem as follows: "Unless action is taken to ensure full management coordination, the results of timber management will become an either-or situation -- good for either timber production or deer and elk production but not for both. This situation need not occur. There can be simultaneous production of timber and deer and elk from the same area."

The forest habitats of primary concern in the present analysis are regenerating or second growth forests in the Coastal Douglas Fir (CDF) and Coastal Hemlock biogeoclimatic zones (Krajina 1965). These immature forest habitats comprise a major portion of the southeast lowlands of Vancouver Island and are increasing on the central and northern parts of the island. Intensively managed second growth stands will be the major forest habitats in future years on Vancouver Island. Thus, silvicultural activities will be the major factor influencing wildlife habitat potential of most areas on Vancouver Island.

The components of the elk/intensive forestry problem have been graphically summarized in Figure 1. The problem interface is habitat; both elk dynamics and silvicultural activities are intrinsically linked by habitat. Forestry activities which change the habitat will also change elk dynamics. The reverse is also true; elk utilization of a habitat can change the habitat and influence future forestry activities, but to a more limited extent. The major concerns of the present analysis are silvicultural impacts on elk ecology.

The major indicators of elk response to habitat changes are, as indicated in Figure 1, habitat utilization, animal condition and population trend. These indicators serve to bound the elk/intensive forestry problem. Knowledge of response to factors other than habitat change must also be incorporated in this system. Predation and climatic factors, which may confound interpretation of habitat use, must be part of the research design.

Presently, intensive forest management is proceeding with little regard for wildlife maintenance or enhancement benefits. The reasons for this lack of coordination are twofold: (1) major policy conflicts exist between forest and wildlife management agencies, and (2) there is inadequate knowledge of utilization of presently available habitat types and population characteristics (home ranges, abundance, productivity, etc.) of wildlife in second growth forests.

Presently, information pertinent to elk dynamics in immature forests on Vancouver Island is non-existent. A recent field study examining seasonal movements and habitat utilization by elk in a mature forest/early regeneration system is the only quantified information on elk ecology on Vancouver Island (Janz, in prep.).

Therefore, information on elk ecology in unmanaged second growth forests and data quantifying the impacts of various intensive forest treatments on elk dynamics are required. This implies two frames of reference for research on the elk/intensive forestry problem: an immediate and a long range. The immediate frame of reference is necessary prior to extensive hypothesis testing in order to establish an adequate ecological data base. This "baseline" information will allow subsequent delineation of adjacent control vs. treatment comparisons and monitoring of pre and post treatment sites. The

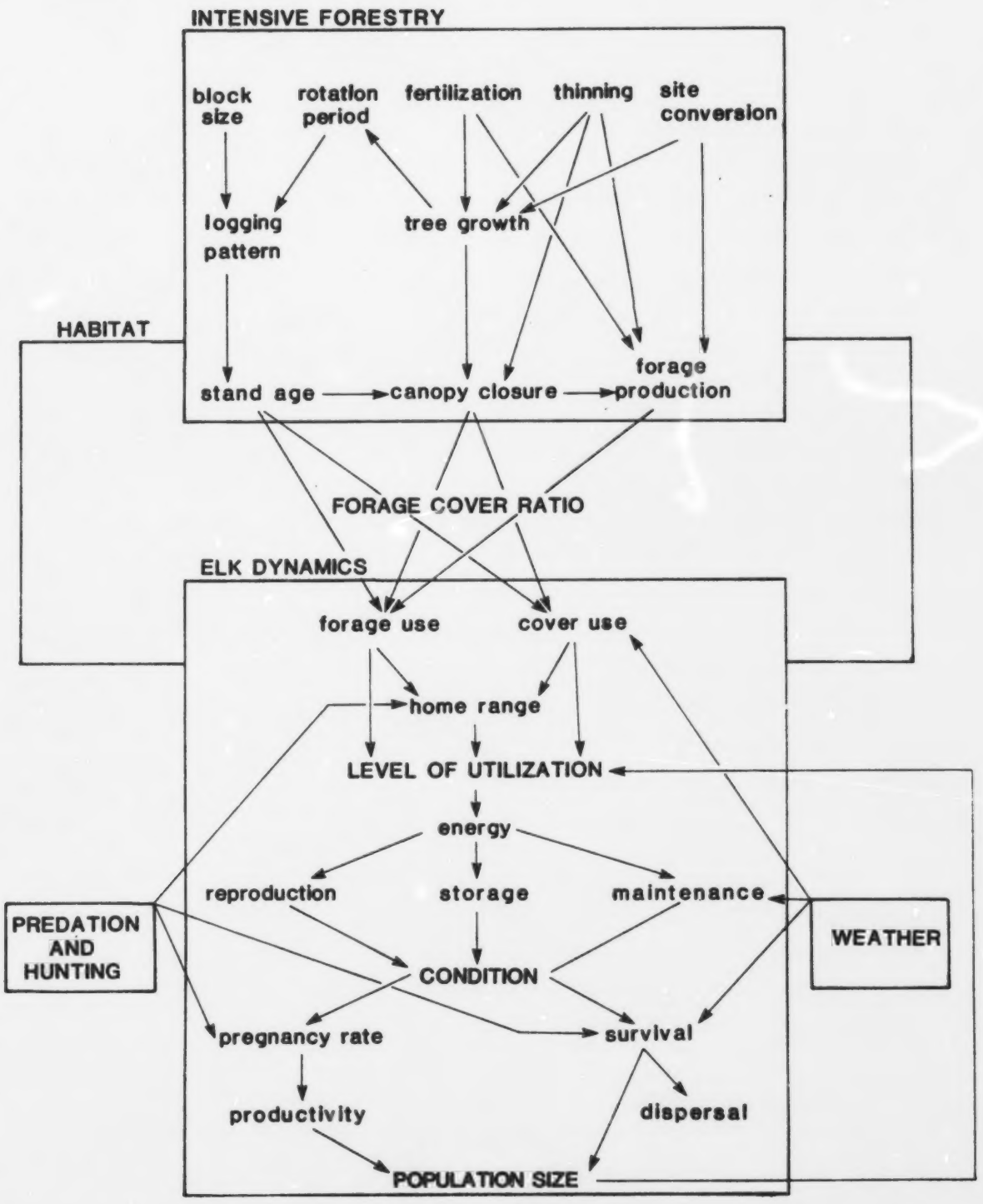

Fig. 1. Summary of interrelationships between components of the elk/intensive forestry problem.

long range frame of reference should involve the testing of functional and numerical responses of elk to various silvicultural treatments, and ultimately involve derivation of a management system that can predict habitat suitability based on the spatial and temporal arrangement of cover and forage types within a managed forest.

5 PROBLEM BREAKDOWN

5.1 Problems Under Consideration

Both the baseline data requirements and testing of elk/forestry interactions can be broken into a common set of research topics. A logical approach would entail monitoring animal movement and habitat use patterns, describing the characteristics of available habitat, and assessing the effectiveness of habitat use strategies by animal condition and population vigour indicators. Comparative data from herds occupying different ecosystems and monitoring response to habitat manipulation could then be collected, with concomitant measurement of extrinsic factors such as predation and weather. The following sequence of topics, using the above approach, is presented in order of priority.

5.1.1 Habitat Utilization

Specific elk habitat use and seasonal movement patterns are currently undocumented in second growth forests on Vancouver Island. In order to determine the response to intensive forest management, and also to manage elk on a habitat basis, knowledge of habitat utilization and delineation of seasonal home ranges are prerequisites.

5.1.2 Vegetation and Physical Environmental Parameters

Impacts of intensive forest management on vegetation and physical environmental parameters, particularly in regard to elk forage and cover requirements, are poorly documented. Vegetation characteristics such as species composition, forage production, forage quality, forage availability,

stand density and canopy closure will change with different forest treatments, and over time. Likewise, important physical environmental characteristics within stands such as snow depth, snow density, air temperature and wind speed may be modified through different forest treatments. The magnitude and duration of these changes require documentation.

5.1.3 Animal Condition

Relative elk condition, by season and available habitat types, within second growth forests on Vancouver Island is undocumented. Information on condition is necessary to assess physiological responses of elk to secondary succession habitats and intensive forest management.

5.1.4 Population

Population information, including distribution, abundance, productivity, mortality and dispersal, is either poor or completely lacking for elk herds in second growth forests on Vancouver Island. Population information is required to assess numerical responses of elk herds to second growth forests and intensive forest management.

5.1.5 Predation

The potential influence of predation (especially wolf predation) on elk habitat utilization, condition and population trends is high. Presently, the level of predation is undocumented. Predation in the form of legal hunting is one factor that is under complete control and can be manipulated to meet specific objectives.

5.1.6 Habitat Enhancement

Procedures for enhancing elk habitat such as propagation of browse species and fertilization of specific ranges to improve forage production and quality have not been adequately investigated on Vancouver Island.

5.2 Scope of Present Knowledge

As mentioned in the problem definition, information pertinent to Roosevelt elk dynamics in immature forests on Vancouver Island is non-existent. A recent study of elk dynamics in a mature, early generation forest system on Vancouver Island will provide only limited baseline data for research studies in second growth forests.

The following is a review of elk literature pertinent to the six identified problems. Literature examined deals with two subspecies of North American elk, Rocky Mountain (Cervus elaphus nelsoni) and Roosevelt (C. e. roosevelti). The majority of this literature relates to Rocky Mountain elk. While Rocky Mountain elk are distributed principally in the central to northern Rocky Mountains, Roosevelt elk are located in the coastal areas of the Pacific Northwest (Boyd 1968); for this reason much of the Rocky Mountain elk literature, especially in regard to habitat utilization, may not be directly applicable to Vancouver Island.

5.2.1 Habitat Utilization

5.2.1.1 Cover Requirements

Cover requirements for elk are not well understood and probably vary with season, climate and biogeoclimatic zone. Three types of cover are discussed in the literature: thermal, security and special cover. Thermal cover is important for the maintenance of body temperature (McEwen and Whitehead 1970; Beall 1974), while security cover provides an animal protection from view and is of major importance in deterimining elk use of disturbed habitats (Lyon 1975; Marcum 1975). Size of cover patches, stand height and density, degree of canopy closure and availability of forage are all important criteria in determining suitability of cover.

Generally, thermal cover is considered to consist of stands of mature coniferous trees. For example, Thomas et al. (1976) have defined thermal cover for Rocky Mountain elk in the Blue Mountains of Oregon as being a stand

of coniferous trees 40 feet (12.2 m) or more in height, with average crown closure exceeding 75%. Use of thermal cover in winter has been found to be influenced by snow depth (Leege and Hickey 1977) and temperature (Beall 1974). Staines (1976) reported that windchill was the most important factor associated with winter shelter-seeking behavior by red deer. In second growth forests on Vancouver Island, thermal cover requirements will likely vary with season, elevation, latitude, and biogeoclimatic zone; an important consideration will be the availability of suitable stands to serve as thermal cover.

Security cover requirements vary with the degree of human disturbance within a habitat, and possibly the level of predation. Studies of Rocky Mountain elk in Montana have documented temporary movements away from human disturbed or occupied habitats (Lyon 1975; Marcum 1975). Vehicle traffic has been shown to reduce the availability of elk habitat adjacent to roads (Hershey and Leege 1976; Rost and Bailey 1979). In second growth forests on Vancouver Island, roads, human activity and predation levels will likely be important determinants of security cover requirements; changes in stand density resulting from thinning practices will be an important consideration.

Special requirements of cover for calving include both security and thermal cover for the cow and calf. It is also important that the cover types occur in conjunction with areas of high forage availability and quality (Altmann 1952; Phillips 1966; Reichelt 1973; Black et al. 1976). A description of optimum Rocky Mountain elk calving habitat in Oregon (Black et al. 1976) includes provisions for:

1. an area with gentle slope (usually less than 15%), and
2. a mixture of tree cover, shrubs and forage, all in close proximity to water (within 305 m [1000 ft]).

Rutting activities are often associated with utilization of specific habitat types, although the importance of special cover requirements at this time of year are confounded by behavior, hunting pressure, and general shifts in habitat use associated with foraging (Schoen 1977).

5.2.1.2 Forage Requirements

Forage requirements can be considered either: (1) by forage species (quality and quantity) required to support an elk herd (i.e. food habits), or (2) by the quantity and quality of the ecosystem required to produce that forage.

Forage habitat requirements are difficult to assess since forage is produced to some degree on both cover and non-cover areas (Thomas et al. 1976). The general approach has been to assume that cover habitats are different from optimum forage habitats and that there is no overlap (Black et al. 1976). This approach fits in well with a classic forage cover ratio management theory, whereby cover and forage habitats are provided in certain proportions to satisfy animal requirements and to produce the optimum habitat use (Thomas et al. 1976). However, this approach neglects importance of habitat types such as uneven-aged mature timber, which may provide high forage value for ungulates in winter and summer in addition to providing shelter (Janz, in prep.). Immature stands treated by various thinning regimes may provide foraging habitat (5.1.2).

For non-cover areas, important criteria in determining elk use of the area for foraging activities include the quality and quantity of forage available, and the proximity of the area to cover types and water. Habitats which produce a high quantity and quality of forage include riparian habitats, meadows, natural forest openings and created forest openings. Riparian habitats and wet meadows generally produce a higher quality and quantity of forage than drier habitat types (Patton and Judd 1970; Peek et al. 1976; Collins et al. 1978). In this regard, use of areas associated with water by both Rocky Mountain and Roosevelt elk has been demonstrated (Swanson 1970; Lonner 1976; Schoen 1977; Pedersen et al. 1979). Timber edge in association with forage areas is also important in determining elk use of an area for foraging. Both Rocky Mountain and Roosevelt elk investigations have shown that use declines with increasing distance from edge (Harper 1971; Thomas et

al. 1976; Janz 1980). On the basis of this effect, optimal width of a forage area for Rocky Mountain elk in Oregon has been estimated to be 366 m (1,200 ft.), such that no point is farther than 183 m (600 ft) from an edge (Thomas et al. 1976). The importance of cover adjacent to forage areas requires further study, especially under conditions when forage is limited (ESSA 1981:132).

Elk use of created openings (such as clearcuts) is, in addition to the size of the opening, influenced by the age of the opening and the amount of slash and down timber in and around the opening (Lyon 1976). Lyon (1976) found that for Rocky Mountain elk in Montana presence within a clearcut increased with vegetation height and reached a maximum when vegetation was 1.5 m (4 feet) high; however elk response to vegetation height was reduced when slash or down timber material exceeded 0.5 m (1.5 feet) in depth and when the opening size exceeded 40 ha (100 acres). It is anticipated that the amount of debris created by harvesting second growth even-aged stands will be reduced in comparison to old growth, depending on utilization standards. However, debris associated with thinning activities may have adverse effects on elk utilization of these areas (5.1.2).

Elk food habits have been investigated by numerous workers (Kufeld 1973; Packee 1975), but comparison of species shows wide variability between different geographic areas. Data from Janz (1980) indicate major seasonal differences in Roosevelt elk diets on Vancouver Island between winter and spring periods. Winter diets were dominated by coniferous browse, deciduous browse and ferns, while spring and early summer diets showed pronounced shifts to a diet dominated by grasses and deciduous browse. This shift in diet corresponded to a seasonal shift in home range to wet meadows/bogs and snow slides during spring and early summer periods. Elderberry (Sambucus racemosa) was a preferred species, receiving heavy utilization especially in the early winter months.

The liquidation of old growth stands and replacement by managed second growth will generally result in a decrease in understory species diversity and abundance (Wallmo and Schoen 1980). The possibility of reduced choice for dietary selection and subsequent effects on animal condition should be addressed in the research program (ESSA 1981:133).

5.2.1.3 Home Range

The concept of home range has been frequently discussed in the biological literature. The most widely accepted definition of a home range is probably that of Burt (1943:347) who defined it as "that area traversed by the individual in it's normal activities of food gathering, mating, and caring for young." Phillips et al. (1973) mentioned area utilized during a defined period, and Harestad (1979) emphasized the importance of defining home range as being either daily, seasonal, or lifetime in order to be meaningful.

The size of an animal's home range appears to be related to energy requirements and habitat productivity. McNab (1963) noted the correlation between body size and home range size. Not only does an animal's size greatly affect the maximum area that can be covered, but larger animals require more energy to fulfill their requirements, and therefore must roam more to collect nutrients. Other factors that apparently influence the size of an individual's home range include population density (Tester and Siniff 1965; Sanderson 1966), season (Tester and Siniff 1965; Rogers et al. 1978, Harestad 1979), interspecific interactions (Tester and Siniff 1965), latitude (McNab 1963; Harestad and Bunnell 1979a), age (Martinka 1969; Harestad and Bunnell 1979a), terrain (Harper 1971), and precipitation (Harestad and Bunnell 1979a).

Harper (1971) concluded that terrain was the most important factor regulating the home range size of Roosevelt elk (Cervus elaphus roosevelti) in Oregon. The accumulated average home range diameter for both sexes was 1.4 miles in deep canyons, 2.3 miles along ridge tops and in moderate canyon

terrain, and 3.3 miles in flood plains. In that study, bulls had consistently larger home ranges than cows, regardless of terrain. Habitat availability and productivity associated with the terrain types was not reported.

Seasonal home range size studies have noted the reduced size of elk home range during winter. In comparison to winter home ranges, summer-fall home ranges have been measured to be from 1.5 (Hash 1973) to 5.0 (Craighead et al. 1973) times larger. Alexander (1973) recorded an annual home range size for Roosevelt elk in Alaska that was 7.1 times larger than the winter home range, and attributed the difference to variations in habitat types, snow depth, seasonal abundance of forage, and sex composition of the herd. Summer-fall home ranges for Roosevelt elk on Vancouver Island have been reported being 2 to 3.5 times larger than average winter home range size (Janz, in prep.). Reduced winter home range size appears to be a function of severity of weather (Hash 1973), lower food intake associated with declining forage quality, and reductions in metabolic rate (Moen 1973).

No seasonal shifts or reductions in home range were observed in a herd of Rocky Mountain elk in Oklahoma presumably because of adequate annual forage availability (Waldrip and Shaw 1979) due to mild winters. Cow home ranges were determined to average 313 ha (733 acres) with calf home ranges averaging 271 ha (669 acres) by 10 August, suggesting that home range size was a function of the age of the animal.

The majority of existing studies of elk home range have been conducted with Rocky Mountain elk in interior mature forests and extensive cutover habitats. Baseline home range information gathered in this study will allow monitoring of home range size of Roosevelt elk in intensively managed and unmanaged second growth forests. Hypotheses concerning changes in home range size in response to resource manipulation (i.e. increasing forage production) can be explored, although habitat use patterns and intensity also require documentation as home range size may be enforced to a large extent by animal behavior.

5.2.1.4 Migration

Seasonal movements of ungulates are generally accepted to be in response to seasonal fluctuations in food availability (Orr 1970). Numerous studies have attempted to determine the stimulus (or stimuli) that initiates migratory movements. The most frequently reported factor initiating fall migration of Rocky Mountain elk is increasing snow depth on the summer range (Norberg and Trout 1957; McLean 1972; Hash 1973; Sweeney and Steinhoff 1976). Both Roosevelt and Rocky Mountain elk have been noted to move to lower elevations in response to snow storms, but return to the summer range a few days later when the snow melts (Troyer 1960; Hash 1973). Boyd (1970) suggested that hunting pressure may push some elk on to winter ranges early in the fall, but the main migration starts after the onset of winter weather. Janz (1980) suggested that the onset of cooler temperatures and subsequent weathering and desiccation of forage species at higher elevations resulted in fall migration of Roosevelt elk on Vancouver Island.

Return to the summer range by Rocky Mountain elk has been reported to occur in response to receding snowline (Anderson 1954; Altmann 1956; Anderson 1958; Stevens 1966; Boyd 1968), spring greenup (Brazada 1953; Moran 1973; Sweeney and Steinhoff 1976), or a combination of these factors (Capp 1968; McLean 1972). McLean (1972) suggested that temperature change may also initiate spring movements of elk, apparently independent of snowline retreat. Factors initiating spring migration in Roosevelt elk appear to be associated with timing of spring greenup at higher elevation natural openings, although some animals were observed to calf on winter ranges prior to migration to summer ranges (Janz and Lloyd 1977).

Traditional use of migratory routes and seasonal ranges by Rocky Mountain elk has been frequently documented (Brazada 1953; Anderson 1958; Picton 1960; Knight 1970; Craighead et al. 1972; McLean 1972; Shoesmith 1979), particularly for years with similar snow conditions (Capp 1968). Craighead et al. (1973) suggested that calves probably learned seasonal movements from the cow.

The existence of non-migratory herds of both Rocky Mountain and Roosevelt elk has been recorded for a number of areas (Schwartz and Mitchell 1945; Brown 1964; Boyd 1968; Knight 1970; Craighead et al. 1972; Craighead et al. 1973; Franklin et al. 1975; Waldrip and Shaw 1979). Reduced snow depths due to geothermal activities (Craighead et al. 1973), and mild, snow-free winters that do not impose quantitative food limitations (Waldrip and Shaw 1979) have been noted as reasons for Rocky Mountain elk occupying year round ranges. It is possible that an increase in forage availability resulting from various silvicultural practices will alter migratory behavior of elk. Depending on the spatial and temporal patterns and response of forage to these treatments, spring migration may be delayed by the creation of suitable spring forage adjacent to winter ranges. At the extreme, migratory herds may become resident if seasonal habitat requirements can be produced within the same ecosystem unit.

5.2 Vegetation and Physical Environmental Parameters

5.2.1 Responses to Thinning

Thinning can be viewed as a shift of the forest stand to an earlier successional stage through reduction of basal area and canopy cover of the overstory (Bunnell and Eastman 1976). The impact of this shift on understory vegetation is not well documented. Jameson (1967) has found that the relationship between the biomass of the understory and degree of crown closure is of a negative exponential form. In a thinning experiment established at Shawnigan Lake, Vancouver Island in 1971, thinning caused more light to penetrate through the tree canopies and increased the undergrowth biomass; heaviest thinning was the most beneficial to understory growth (Stanek et al. 1979). Dealy (1975) studied the understory response to 5 thinning levels in a 47-year-old lodgepole pine stand in central Oregon, and reported that understory cover had exceeded prethinning levels by the third year, and after 9 years the stands were producing from 300 to 1000 percent more understory

cover. Heavier thinning levels tended to produce greater understory response. Bunnell and Eastman (1976) postulate that given the varying relationship between crown closure and basal area, the reduction in canopy necessary to stimulate significant understory response will vary between ecosystems.

Slash from thinning activities has been observed to have negative effects on ungulates, impairing access and reducing understory growth (Dell and Ward 1969). Dealy (1975) reported that slash from thinning (19-foot spacing) resulted in deer avoidance, regardless of forage production. After 5 years of slash deterioration, 30 to 40 percent of the area was available, increasing to 65 to 75 percent availability after 9 years.

5.2.2.2 Responses to Fertilization

Studies in eastern North America have suggested that fertilization can increase understory growth, thereby increasing the carrying capacity of the area (Wood and Lindzey 1967; Ward and Bowersox 1970). However, the response of understory vegetation, especially in west coast ecosystems, to fertilization is not well documented. In the Shawnigan Lake experiment on Vancouver Island, Stanek et al. (1979) found that fertilization alone caused an overall decrease in understory biomass through promotion of tree crown growth and resultant decreases in light available to understory vegetation. The interaction between thinning and fertilization had a significant positive effect on one test species (Gaultheria shallon) with heavy thinning and moderate fertilizer applications resulting in the highest growth.

A non-silvicultural application of fertilizer (27-14-0) in the Adam River watershed on Vancouver Island (Fish & Wildlife Branch, Ministry of Environment, B.C.) has indicated no significant effects of fertilization on the quality (crude protein content) of Vaccinium and Salix winter twigs (Janz, pers. comm.).

5.2.2.3 Physical Features

As previously discussed, manipulation of forest stands by various silvicultural treatments will affect the ability of these stands to provide security, thermal cover and forage. Snow characteristics such as depth, density, and hardness are major factors determining ungulate distribution and habitat use during the winter period (for review, see Bunnell 1978). Of particular concern is the influence of canopy closure on snow interception and available understory vegetation (Harestad and Bunnell 1979b) and resultant consequence on energetics (expenditure of energy via locomotion vs. food intake).

The trade-off between snow interception and understory biomass in second growth forests requires documentation. It is possible that the degree of canopy reduction required to stimulate significant understory production by thinning operations will result in negligible snow interception benefits. This implies that treatments must be designed to create a mosiac of forage and shelter habitat types. On winter ranges subject to high snowfall, winter mortality will be high unless forage and cover requirements can be satisfied within one habitat type.

5.2.3 Animal Condition

Indices of animal condition can be used to compare nutritional status of animals or populations inhabiting areas that may differ in environmental attributes (habitat conditions) or management prescription (Janz 1979). Using metabolic or endocrine parameters, it is possible to detect not only extreme environmental changes that may be evident by changes in demographic characteristics, but also more subtle differences between local habitats. This may allow more rapid evaluation of the results of habitat manipulation than standard demographic techniques, estimates of fat reserves, or direct habitat evaluation (Seal 1977).

Fecal nitrogen indices have been demonstrated to have strong positive correlations with forage quality (nitrogen intake), and appear to offer an indirect (non-contact) assessment of animal condition (Janz 1979). Fecal nitrogen values collected for Roosevelt elk in a mature forest/early regeneration system on Vancouver Island (Janz 1980) range from a low of approximately 1.5% December through March to a high of approximately 4.2% in June. Within-sample variation is low (coeffecient variation less than 10%); fecal N for calves may be higher than adults at a given sample date due to smaller mouth structure and subsequent higher selectivity of forage species and plant parts. Comparative data collected by Gates (1979) on captive Rocky Mountain elk in Alberta indicates a similar range of nitrogen values and a significant relationship with seasonal body weight change.

Pedersen and Pedersen (1975) have reported base line blood chemistry values for Rocky Mountain elk. Weber and Bliss (1972) reported blood chemistry values for both captive and free-ranging Roosevelt elk.

5.2.4 Population

Population studies of elk, particularly Roosevelt elk, are in an early stage of development: numbers, sex and age structure, mortality, and natality have been documented in many cases, however, rarely simultaneously from the same population and rarely with a high degree of accuracy. Maximum rates of increase for unexploited elk populations have been estimated to range from 20-30% (Murie 1951; Murphy 1963; Flook 1970; Kimball and Wolfe 1979). Methods of estimating mortality have included seasonal classification counts and kill samples with follow-up life table analysis. Productivity has been estimated indirectly through measurement of pregnancy rates and directly through calf/cow ratios interpreted from classification counts. Pregnancy rates have been shown to vary significantly between yearlings and adults (Flook 1970; Trainer 1971). Animal condition is an important factor determining age-specific pregnancy rates and productivity (Trainer 1971; Thorne et al.

1976). On Vancouver Island, Janz (1980) has estimated Roosevelt elk adult pregnancy rates of approximately 89 percent. Productivity estimates, as measured through calf/cow ratios in late summer or early fall, have shown a range of values from 40 - 60 calves/100 cows (Harn 1960; Boyd 1970; Follis and Spillet 1974; Kuttel 1975; Kimball and Wolfe 1979; Janz 1980). Specific values measured from Roosevelt elk on Vancouver Island in mature timber/early regeneration habitats have indicated a range of 43 - 52 calves/100 cows (Janz 1980).

Dispersal has been little studied to date although Janz[a] indicated that herds on northern Vancouver Island in mountainous areas are generally watershed specific. Elk tend to display a relatively low dispersal rate as evidenced by range expansion studies, perhaps due to their social behavior (Caughley 1963).

5.2.5 Predation

Predation on ungulate populations has in some cases been shown to be a major limiting factor on population growth (Mech 1977; Peterson 1978). Relatively little is known of the impact of predation on elk populations, especially Roosevelt elk. Studies of other ungulates have shown that predatory impacts are dependent upon a complex of factors including prey density, predator-prey ratio, prey selectivity, food consumption and the use of alternate prey by the predator (Messier 1979).

In a study of wolves in the Rocky Mountain National Parks, Cowan (1947) documented a relatively high proportion (47%) of the wolf diet to consist of Rocky Mountain elk. He also observed that wolf predation on elk was not confined to the young and old, but considered this to be related to a 50% surplus or overstocking of elk on winter ranges.

Carbyn (1975), working in Jasper National Park, found that Rocky Mountain elk occured in 46% of wolf scats collected in summer, but only in 11% of wolf scats collected in winter. Wolf predation on elk (30%) was secondary to predation on mule deer (43%) in the annual diet.

[a] Personal files of the author: Ministry of Environment, 2569 Kenworth Road, Nanaimo, B.C.

In a study of wolf food habits on Vancouver Island, Scott (1979) found 28% occurrence of Roosevelt elk by relative weight in wolf scats collected over the study period (May - October). A high use of elk calves during summer months (June - August) was documented; however, scat analysis did not allow separation of calves and adults after August, and, therefore, relative use of elk calves at other periods could not be compared.

In a Rocky Mountain elk calf predation study in Idaho, Schlegel (1978) found that of 89 radio-collared calves, 44% were lost to predators (primarily black bear). Annual calf predation losses (over four years of study) varied from 35 - 70%. A bear removal study appeared to result in increased calf survival.

A five year study of cougar predation in Idaho (Hornocker 1970) indicated that cougar selected for young elk and animals in poor condition, and had little influence in determining population levels of elk or mule deer.

Vancouver Island supports viable populations of large predators (black bear, cougar, and wolf). Management concern for the welfare of deer and elk populations has recently increased in response to the impact of high wolf predation, especially on deer (Hebert et al. 1981). As the potential for predator influence (especially wolf) on elk habitat use and population vigour is high, investigation of predator-prey interactions must be a component of the research program (ESSA 1981:134).

5.2.6 Habitat Enhancement

While numerous techniques are available for habitat enhancement activities, the use of browse propagation has been most widely reported in the literature (Orme and Leege 1975; Densmore and Zasada 1978; Holloway and Zasada 1979). The success of browse propagation for specifically enhancing elk habitat has not been reported, though experimental testing of propagation of preferred forbs to reduce browse damage is in progress in Washington (Campbell and Evans 1975).

Other habitat enhancement techniques available include release of browse species through thinning or removal of competition, prescribed burning, non-silvicultural fertilization, browse rejuvenation (cutting of older trees to encourage sprouting), use of browse ways or openings in dense stands, and direct planting of browse species (from seed) (USDA 1969). Few of these techniques have been tested on elk range, particularly Roosevelt elk range.

High site conversion, used principally as a forest treatment to convert brush and hardwoods to higher yield conifers, may in some instances improve habitat for elk. Conversion techniques primarily utilize tractor scarification or harvesting merchantable timber, though experimental techniques such as slash and burn, spray and burn, and high-lead scarification are being tested in Oregon and Washington (Dimock et al. 1976).

Four B.C.F.W. enhancement projects are presently in progress on Vancouver Island. These include:

(1) Shaw Creek - Sambucus propagation experiment.
(2) Adam River - non-silvicultural fertilization experiment
(3) Salmon River - browse planting.
(4) Elk River - removal and control techniques for Alnus, and propagation of Salix and Populus.

IWIFR-based research on enhancement techniques will be minimal. Results from other segments of the research program will aid management activities related to elk habitat enhancement.

5.2.7 Impacts on Agricultural Resource

Intensive forest management stand prescriptions have potential to improve elk habitat. Concomitant with increasing elk numbers, the potential for conflict with other resource users increases. Although farming-ranching activities on Vancouver Island are localized, recent expansion and conversion of forest land to pasture has resulted in increasing elk damage to crops. Implications of improving elk habitat in proximity to ranching activities is a concern to the managers and users of both resources. While manipulation of elk numbers to meet specific objectives, such as damage control, is a practical management tool, elk response to various habitat manipulation

treatments has not been adequately investigated. Results from a major research program on elk/intensive forestry interactions should provide information that will allow the use of habitat manipulation as an effective management tool to meet specific objectives related to elk distribution, numbers, and habitat use. As an example, if elk are found to avoid certain habitat treatments, management efforts could be directed at creating buffer strips of these treatments adjacent to agricultural interests.

5.2.8 Summary of Scope of Present Knowledge

As discussed in section 5.1 the majority of elk research and literature pertains to Rocky Mountain elk. The following table summarizes the division of present knowledge between these two subspecies.

Table 1. Summary of references, listed by subject, pertaining to Rocky Mountain and Roosevelt elk

Subject	Rocky Mountain elk (C.e. nelsoni)	Roosevelt elk (.C.e. roosevelti)
Habitat Utilization		
thermal cover	Beall 1974, Leege and Hickey 1977, Thomas et al. 1976.	
security cover	Lyon 1975, Marcum 1975, Hershey and Leege 1976, Rost and Bailey 1979	
calving cover	Johnson 1951, Lyon 1976 Phillips 1966, Reichelt 1973	
forage habitat requirements	Lonner 1976, Lyon 1976 Thomas et al. 1976, Schoen 1977, Pedersen et al. 1979	Swanson 1970, Harper 1971, Janz 1980
food habits	this listing is extensive: i.e. Kufeld (1973) presents 48 Rocky Mountain elk food habits studies	Harper et al. 1967, Harper 1971, Lemos 1971, Packee 1975, Janz 1980

Table 1. (Cont)

home range	Martinka 1969, Knight 1970, Craighead et al. 1972, Craighead et al. 1973, Beall 1974, Schoen 1977, Waldrip and Shaw 1979	Harper 1971, Alexander 1973, Franklin et al. 1975 Janz, in prep.
migration	Anderson 1954, Norberg and Trout 1957, Picton 1960, Bendt 1962, Bowhay 1968, Boyd 1970, Judd 1971, Craighead et al. 1972, McLean 1972, Hash 1973, Moran 1973, Sweeney and Steinhoff 1976, Shoesmith 1979	Harper 1971, Janz 1980
Animal condition		
fecal nitrogen	Gates 1979	Janz 1980
blood parameters	Pedersen and Pederson 1975	Weber and Bliss 1972
Population		
rate of increase	Murphy 1963, Flook 1970, Schoen 1977, Kimball and Wolfe 1979.	Batchelor 1965, Kuttel 1975
mortality	Picton 1961, Boyd 1970 Flook 1970, Kimball and Wolfe 1974, Schoen 1977, Kimball and Wolfe 1979.	Harper et al. 1967.
recruitment	Anderson 1958, Knight 1970, Kimball and Wolfe 1974, Schlegel 1978.	Harn 1960, Harper et al. 1967, Trainer 1971, Janz 1980.
productivity	Flook 1970, Boyd 1970, Follis and Spillet 1974, Schoen 1977, Kimball and Wolfe 1979.	Harn 1960, Trainer 1971, Kuttel 1975, Janz 1980, Smith 1980.
Predation	Cowan 1947, Hornocker 1970, Carbyn 1975, Schlegel 1978.	Scott 1979.

5.3 Unknowns and Specific Vancouver Island Roosevelt Elk/Intensive Forestry Problems

Each of the components of the elk/intensive forestry problem, as previously outlined, can be broken into more specific segments. Each segment represents a presently unknown facet of applied elk ecology in second growth forests on Vancouver Island. Knowledge on each of these specific problems is probably requisite for development of a comprehensive elk/forestry management system. Though certain problems will likely shift in importance and new questions arise as the project progresses, the following list is presented in a priorized fashion.

5.3.1 Habitat Utilization

a) The important physical characteristics of thermal cover -- size, shape, stand characteristics, elevation, slope, aspect, degree of canopy closure, availability of forage. An important associated question is: can regeneration stands under 80 years of age (approximate rotation period) serve as adequate thermal cover? Under what conditions?
b) The important physical characteristics of security cover -- height and stand density.
c) The minimum area requirements for security and thermal cover patches.
d) Calving cover availability and requirements.
e) The importance of juxtaposition of cover patches and forage areas.
f) The seasonal food habits and preferred forage species.

5.3.2 Vegetation and Physical Environmental Parameters

a) The influence of silvicultural treatments on plant species, quality, quantity, availability and composition.
b) The influence of spacing debris on elk mobility and habitat utilization.
c) The influence of silvicultural treatments on physical environmental parameters such as snow depth, snow density and air temperature.

5.3.3 Animal Condition

The relative condition of individual elk in managed and unmanaged forests, and how this condition responds to different silvicultural treatments and/or enhancement projects.

5.3.4 Population

The influence of silvicultural treatments on population condition and growth.

5.3.5 Predation

a) The impact of predation on elk populations, individual animal condition and habitat utilization.
b) The response of predation to silvicultural treatments.

5.3.6 Habitat Enhancement

a) The feasibility and benefits of extensive propagation of forage species.
b) The effects of high site type conversion on elk habitat.
c) The short and long term effects of non-silvicultural fertilization.

6 RECOMMENDED STUDIES

The two frames of reference established earlier in this analysis, the immediate and the long range, are important to recall in terms of recommended studies. The immediate frame of reference should focus on baseline data acquisition; such data (i.e. home ranges, migratory habits, abundance, productivity, present habitat use, etc.) are essential in order to establish appropriate study sites and design for testing hypotheses regarding the unknowns listed above. The long range frame of reference should encompass research testing specific hypotheses and interpreting solutions to these problems.

6.1 Immediate Frame of Reference

The following subjects are recommended for study in second growth forests in order to establish baseline data:

a) Use of present habitat types on a seasonal and diurnal basis.
b) Migratory status of herds and factors initiating migration.
c) Seasonal home range delineation.
d) Seasonal food habits.
e) Animal condition by season.
f) Plant species composition, forage quality and quantity and availability by habitat type and season.
g) Preliminary population characteristics such as abundance, productivity, recruitment and dispersal.
h) Predatory influences.

6.2 Long Range Frame of Reference

Study topics in this research phase should consider specific problems and unknowns presented in section 5.2. Specific hypotheses should be developed once preliminary baseline data are established. These studies should be performed in both untreated and treated second growth study areas.

7 SUMMARY AND CONCLUSIONS

The scope and bounds of the elk/intensive forestry problem have been defined and present knowledge from related research has been reviewed.

Specific problems (or unknowns) associated with the elk/intensive forestry problem on Vancouver Island have been identified.

Recommended studies, defined in an immediate frame of reference and a long range frame of reference, have been presented. From the immediate frame, information will be gained regarding the present abundance and distribution of elk, their home ranges and seasonal movement patterns, and present habitat

utilization, food habits and population parameters. This information (at least in a preliminary form) will be necessary for defining specific hypotheses about elk-silvicultural interactions for which tests will be carried out in the long range frame of reference. This frame will investigate and provide information on a series of habitat - animal related questions. Solution of these questions should provide the basis for developing an elk/intensive forestry management system applicable to the biogeoclimatic zones of Vancouver Island.

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